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Anteromedial tibial tubercle transfer without bone graft*

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ABSTRACT

We followed 30 patients for more than 2 years after anteromedial tibial tubercle transfer for persistent patellofemoral pain associated with patellar articular degeneration. Twelve of these patients were followed more than 5 years. We report 93% good and excellent results subjectively and 89% good and excellent results objectively. The quality of improvement was sustained in all 12 of the patients who were evaluated again after more than 5 years from surgery. When examined separately, 75% of those patients with advanced patellar arthrosis achieved a good result; none of these patients achieved an excellent result. Postoperative continuous passive motion has markedly reduced the incidence of stiffness. Serious complications such as compartment syndrome, infection, and skin slough were avoided completely in 51 consecutive cases. Patellofemoral contact pressure studies in five cadaver knees have shown that anteromedial tibial tubercle transfer can provide substantial reduction of patellofemoral contact stress while helping to balance medial and lateral facet pressures. This surgical procedure is mechanically and clinically successful for alleviating intractable pain related to patellar malalignment and articular degeneration. This procedure enables the majority of appropriately selected patients with malalignment and patellar articular degeneration to resume increased levels of activity with substantially diminished pain.

Recent publications have helped to clarify the appropriate use of anteromedial tibial tubercle transfer in the treatment of patellofemoral pain.13,14 Insall,20,21 DeHaven et al.9 and others have emphasized the importance of a thorough conservative treatment program for patients with patellofemoral pain, but surgical intervention becomes necessary in a small number of patients. Although clinical examination of the knee remains the cornerstone of accurate decision making,9 computerized tomography has been extremely helpful in deciding which patients are appropriate candidates14 for lateral release, realignment, or anteromedial tibial tubercle transfer. Preoperative determination of patellar tilt or subluxation13,34 using computerized tomographic images of the patellofemoral joint through the first 30° of knee flexion permits more accurate selection of an appropriate surgical procedure.

The anteromedial tibial tubercle transfer technique has been previously described,12 but there has been considerable experience with this technique since that time. Many of the patellar realignment procedures described5, 6,19,22,35 do not give net relief of patellofemoral contact stress but are suitable for realignment alone. The Cox modification of the Elmslie-Trillat procedure6 is similar to anteromedial tibial tubercle transfer and provides medialization without tubercle displacement in the anteroposterior plane. Techniques such as the Hauser procedure17 should be avoided because the tibial tubercle is moved posteriorly. There has been difficulty with appropriate patient selection for realignment versus lateral release, and even some reluctance to treat patellofemoral pain patients surgically. Historically,10 there have been many treatment alternatives for persistent patellofemoral pain. Arthroscopic surgery7,13 and lateral release25 have been helpful in the treatment of some disorders that cause anterior knee pain, but relief of articular contact stress in the patellofemoral joint may be desirable when the patellar articular surface is degenerating. In addition, restoration of stable patellar tracking when there is recurrent subluxation18 is important in relieving patellofemoral pain.8 Reider et al.33 pointed out the importance of determining the correct surgical treatment appropriate for a specific

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were treated successfully without surgery over the study period. Lateral retinacular release is the most common surgical procedure recommended and is the procedure of choice for patellofemoral pain related to soft tissue, retinacular strain, or excessive patellar tilt, with or without mild articular cartilage lesions. Anteromedial tibial tubercle transfer is recommended when there is intractable patellofemoral pain associated with moderate or advanced patellar articular degeneration and excessive lateral patellar tilt or subluxation. Less than 2% of all patients with patellofemoral pain required anteromedial tibial tubercle transfer.

Patient followup was achieved by use of a questionnaire and telephone contact in 30 patients to obtain subjective evaluation and information. Patients were questioned about improvement over preoperative status, pain, limitation of activities, and overall satisfaction. Objective followup was obtained in 26 of these patients using a functional knee scale modified for evaluation of patellofemoral pain and instability (Table 1). This scale was felt to be a better indicator of overall patient function than one based on details of clinical examination, such as crepitation. At the objective followup, patients were examined for evidence of residual mechanical difficulty or instability, limp, crepitation, swelling, progression of arthrosis, Q (quadriceps) angle alteration, and functional limitation. A patient was considered to have an excellent result if the knee scale evaluation resulted in a score of 95 to 100 points, a very good result if there was a score of 90 to 94, a good result if the score was 80 to 89, a fair result if there was a score of 70 to 79, and a poor result if the score was less than 70. Preoperatively, all patients had a score of less than 70, intractable pain, signs of patellar articular degeneration, patellar malalignment requiring distal tibial tubercle transfer, and failure to respond to nonsurgical treatment. Four patients had failed to respond to lateral retinacular release.

**Materials and Methods**

Of 51 anteromedial tibial tubercle transfers performed during this study, 31 have been followed for more than 2 years. One of these patients was lost to final followup, leaving 30 patients with an average initial followup of 19 months, and a final followup of 35 months (range, 26 to 50 months). There were 24 females and 6 males with an average age at the time of surgery of 28 years (range, 14 to 56 years), representing a fairly young, active population of patients with significant patellofemoral malalignment (and associated articular breakdown) causing persistent pain that had not responded to conservative management. The mean anteriorization was 10.6 mm (range, 7 to 15 mm). All patients had evidence of patellofemoral articular degeneration and patellofemoral pain. Most of these malalignment patients had a lesser degree of arthrosis involving softened and fibrillated articular cartilage without extensive erosion to bone. The patient population was thus characterized by persistent pain unresponsive to thorough conservative treatment, and moderate articular degeneration related to chronic patellofemoral malalignment. All patients required distal realignment. In these patients, we used anteromedialization as an alternative to a Hauser or Elmslie-Trillat tibial tubercle transfer. Eight patients in this series, however, had severe erosion of patellar articular cartilage to bone (greater than \( \frac{1}{2} \) inch in diameter). This group is reported separately in this study, but is also included with the overall patient group.

In the University of Connecticut School of Medicine Sport Injury Knee Clinics, 93% of all patellofemoral pain patients were treated successfully without surgery over the study period. Lateral retinacular release is the most common surgical procedure recommended and is the procedure of choice for patellofemoral pain related to soft tissue, retinacular strain, or excessive patellar tilt, with or without mild articular cartilage lesions. Anteromedial tibial tubercle transfer is recommended when there is intractable patellofemoral pain associated with moderate or advanced patellar articular degeneration and excessive lateral patellar tilt or subluxation. Less than 2% of all patients with patellofemoral pain required anteromedial tibial tubercle transfer.

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**Patellofemoral Contact Study**

Five preserved cadaver knees were used in this part of the study. The knees were removed from intact cadavers by disarticulation of the hip and ankle. The quadriceps muscles were resected 6 cm proximal to their insertion into the patella. Medial and peripatellar retinacula were released since, according to Goodfellow et al., only an intact patellar tendon is needed to achieve realistic tracking of the patella. Only patellofemoral joints with macroscopically intact articular cartilage were chosen.

The femur and tibia were fixed to the testing device as shown in Figure 2. The frame was constructed of wood with metal hinges, the hinges allowing 0° to 120° of flexion, although a maximum of 90° was used in these tests. Preset testing angles included 0°, 10°, 20°, 30°, 45°, 60°, and 90° of knee flexion, thereby focusing our study on the medial and lateral facets without introducing "odd facet" contact. Force was applied to the extensor mechanism by a No. 5 steel wire suture placed through the quadriceps tendon in a criss-cross fashion. Force was then applied to the extensor mechanism by an Instron 1113 testing machine in a manner similar to that described by Ferguson et al. A force of 490
Figure 1. Anteromedial tibial tubercle shift along an oblique osteotomy plane. The screw is now placed slightly more distal than in the original technique description,11 and the osteotomy bone pedicle is shorter. A, anteroposterior view; B, lateral view—note anteriorization of the tibial tubercle.

N was applied to the quadriceps tendon at all angles of flexion for 2 to 3 seconds and then released. Pressure within each patellofemoral joint was measured using Prescale pressure sensitive film (Fuji Photofilm, New York, NY). Contact areas were also determined from the pressure tracings. The Prescale system consists of two polyester sheets containing reagents that interact to produce color proportionate to the pressure applied to the system. Pressure calibration was accomplished by applying known forces to the film and generating standards for comparison.

A hole was drilled in the patella along the median ridge demarcating the lateral and medial facets, and this was used as a reference point for determining alteration of contact area after the tibial tubercle transfer. Medial and lateral facet pressures and areas were measured for each angle of knee flexion. Anteromedial transfer of the tibial tubercle, was performed in each knee at an osteotomy angle of approximately 45° relative to the coronal plane to achieve anteriorization and medialization of 8 to 9 mm in each plane at the level of the tibial tubercle. A second set of readings at each angle of knee flexion was then taken after further anteriorization (to a total of about 15 mm) of the tibial tubercle. At each anteromedial tibial tubercle transfer point, the bony pedicle was fixed with cortical screws before testing on the Instron. Contact pressures were recorded in mega Pascals (MPa), a standard unit of pressure measurement. A mega Pascal is 10⁶ Pascals, and a Pascal is 1 Newton/cm.² A Newton is defined as the force necessary to accelerate a 1 kg mass by 1 m/sec.² Color intensities on the pressure-sensitive film increased in a nonlinear fashion with increasing pressure. The actual magnitude of contact pressure was determined then by visual comparison with calibration standards obtained by applying known pressures.

RESULTS

Clinical results

At initial followup (19 months), 85% of the patients demonstrated a good to excellent result. At a later followup, the subjective results seemed to improve somewhat. Ninety-
three percent of the patients in this study reported a good to excellent result at a mean follow-up time of 35 months. Objectively, 89% of the patients had a good or excellent result. At objective followup, 35% of the patients (N = 9) were found to have an excellent result, 54% (N = 14) a good or very good result, and 4% (N = 1) a fair result from anteromedial tibial tubercle transfer. Two patients (7%) had a poor result objectively but a fair result subjectively. These patients experienced improvement with surgery but had progressive articular deterioration and arthrosis. One patient required a second surgical procedure (further tibial tubercle anteriorization). This patient improved after the second surgical procedure and now has a good result overall. The other patient rated as poor (objectively) is subjectively satisfied with his status, is working, and does not want further treatment. When examined separately, 75% of the eight patients with advanced arthrosis (Outerbridge 3 to 4) achieved a good result. None of our patients with more extensive patellar articular degeneration achieved excellent results, but all were satisfied and much better than before surgery.

The average preoperative Q-angle was 21.6° (range, 10° to 32°); postoperatively, the average Q-angle was 12° (range, 5° to 20°). Of the 30 patients in the study, 16 required late screw removal from the anterior tibial tubercle because of discomfort.

In the first 25 patients, initial surgery was followed by 4 weeks of complete immobilization in extension followed by active range of motion. Subsequently, patients were managed with continuous passive motion immediately after surgery and both passive and gentle active range of motion at home. Nine of the first 25 patients had stiffness requiring manipulation under analgesia or anesthesia. Since starting knee motion in the immediate postoperative period, stiffness has not been a problem (26 patients—only 5 reported in this study).

Other complications included one late tibial tubercle fracture through the screw hole. This resulted in pain and was corrected completely by reoperation with a bone graft to the fracture site. One patient experienced avulsion of the tibial tubercle on the 3rd day after tibial tubercle transfer. In this patient, a cancellous screw was used for tibial tubercle fixation. Reoperation in the immediate postoperative period resulted in the firm fixation and excellent healing of the tibial tubercle osteotomy using two cortical screws. Two patients developed deep venous thrombosis requiring heparinization, and two patients had prolonged weakness requiring physical therapy after surgery. There were no skin sloughs, infections, or compartment syndromes in 51 consecutive cases.

Recent modifications of the surgical technique and technical suggestions

Although the surgical technique of this operation was originally described in 1983,12 experience has resulted in some

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TABLE 1

<table>
<thead>
<tr>
<th>Pain/instability</th>
<th>No. of available points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Limp</td>
<td>10</td>
</tr>
<tr>
<td>None</td>
<td></td>
</tr>
<tr>
<td>Slight</td>
<td>5</td>
</tr>
<tr>
<td>Severe</td>
<td>0</td>
</tr>
<tr>
<td>Support</td>
<td>10</td>
</tr>
<tr>
<td>Full</td>
<td></td>
</tr>
<tr>
<td>Cane or crutch necessary at times</td>
<td>3</td>
</tr>
<tr>
<td>Weightbearing impossible</td>
<td>0</td>
</tr>
<tr>
<td>Stair climbing</td>
<td>10</td>
</tr>
<tr>
<td>No problem</td>
<td></td>
</tr>
<tr>
<td>Slightly impaired</td>
<td>6</td>
</tr>
<tr>
<td>One step at a time</td>
<td>2</td>
</tr>
<tr>
<td>Unable</td>
<td>0</td>
</tr>
<tr>
<td>Squatting</td>
<td>5</td>
</tr>
<tr>
<td>No problem</td>
<td></td>
</tr>
<tr>
<td>Slightly impaired</td>
<td>4</td>
</tr>
<tr>
<td>Not past 90° of knee flexion</td>
<td>2</td>
</tr>
<tr>
<td>Unable</td>
<td>0</td>
</tr>
<tr>
<td>Instability</td>
<td>10</td>
</tr>
<tr>
<td>Never gives way</td>
<td></td>
</tr>
<tr>
<td>With vigorous activity</td>
<td>5</td>
</tr>
<tr>
<td>Occasionally in daily activities</td>
<td>5</td>
</tr>
<tr>
<td>Often in daily activities</td>
<td>3</td>
</tr>
<tr>
<td>Every day</td>
<td>0</td>
</tr>
<tr>
<td>Pain</td>
<td>45</td>
</tr>
<tr>
<td>None</td>
<td></td>
</tr>
<tr>
<td>Slight during vigorous exercise</td>
<td>40</td>
</tr>
<tr>
<td>Moderate with vigorous exercise</td>
<td>35</td>
</tr>
<tr>
<td>Severe after vigorous exercise</td>
<td>25</td>
</tr>
<tr>
<td>Severe after walking 1 mile</td>
<td>20</td>
</tr>
<tr>
<td>Severe after walking less than ½ mile</td>
<td>10</td>
</tr>
<tr>
<td>Constant and severe</td>
<td>2</td>
</tr>
<tr>
<td>Swelling</td>
<td>10</td>
</tr>
<tr>
<td>None</td>
<td></td>
</tr>
<tr>
<td>With giving way</td>
<td>7</td>
</tr>
<tr>
<td>On severe exertion</td>
<td>5</td>
</tr>
<tr>
<td>On mild exertion</td>
<td>2</td>
</tr>
<tr>
<td>Constant</td>
<td>0</td>
</tr>
</tbody>
</table>

Scoring of overall surgical result

95-100 Excellent
90-94 Very good
80-89 Good
70-79 Fair
<70 Poor

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*Modified from Ref. 26.
improvements. This operation is technically demanding, and initial practice on cadaver specimens is advisable.

Computerized tomography (CT) of the patellofemoral joint (with midtransverse patellar images at 0°, 15°, 30°, and 45° of knee flexion and standing alignment reproduced in the scanner gantry) provides valuable information regarding patellar “tracking” as the patella engages the trochlea in early knee flexion. The posterior femoral condyles provide an anatomically more consistent reference line for determining patellar tilt. We believe that abnormal lateral tilt, with or without associated subluxation, is a major cause of patellar arthrosis. CT, therefore, is a sensitive radiographic technique for evaluating patellar pathomechanics. Also, based on earlier findings, it is now possible to determine who will be likely to attain improved patellar alignment with anteromedialization, lateral retinacular release, or soft tissue re-alignment. Anteromedialization of the tibial tubercle gives excellent restoration of normal patellar tracking when comparing detailed CT evaluations of patients before and after this surgery. An earlier study showed that there is particularly good improvement of tilt following anteromedial tibial tubercle transfer. The improvement of alignment, however, may be no better than with other realignment procedures. The main advantage is concomitant reduction of patellar contact stress.

Currently, anteromedial tibial tubercle transfer is our procedure of choice for unloading a degenerated and painful patella that needs reduction of articular contact pressure at the time of realignment. Our findings demonstrate the efficacy of this procedure for unloading a deficient patella. Substantial risks are inherent in the Maquet procedure; we believe anteromedial tibial tubercle transfer to be a safer alternative when performed as described here. Anteromedial tibial tubercle transfer is particularly desirable when patellar articular degeneration is secondary to malalignment and the surgeon wishes to achieve slight medialization of the patella as well as anteriorization of up to 15 mm.

The initial skin incision should be linear, and skin undermining should be minimal. Lateral release is extended across the vastus lateralis obliquus component of the vastus lateralis, leaving the main vastus lateralis tendon intact. The osteotomy plane, deep to the tibial tubercle, should generally be fairly steep, allowing 12 to 15 mm of anteriorization of the tubercle when the bone pedicle is shifted anteromedially along the osteotomy plane. Also, it is extremely important to be sure that the osteotomy plane is uniform so that there will be good bone-to-bone contact after moving the bone pedicle. Care should be taken at all times to avoid osteotomy through the posterior tibial cortex and to avoid cutting or injuring the neurovascular structures in this area.

The bone pedicle may be shortened to a length of approximately 5 to 6 cm without any evident change in healing. Pedicle fixation is generally achieved with cortical bone screws, securing the pedicle to the posterior tibial cortex. Particular care in drilling and tapping through the posterior cortex will avoid injury to vessels and nerves behind the tibia. If there is any question about the stability of fixation,
two screws are used instead of the usual one. Screws are now placed slightly more distal in the tubercle (Fig. 1). The vastus medialis obliquus is advanced when needed to balance the vastus lateralis obliquus and medialis,16 leaving the main vastus lateralis tendon intact. The osteotomy plane, deep to the tibial tubercle, should generally be fairly steep, allowing 12 to 15 mm of anteriorization of the tubercle when the bone pedicle is shifted anteromedially along the osteotomy plane. Also, it is extremely important to be sure that the osteotomy plane is uniform so that there will be good bone-to-bone contact after moving the bone pedicle. Care should be taken at all times to avoid osteotomy through the posterior tibial cortex and to avoid cutting or injuring the neurovascular structures in this area.

The bone pedicle may be shortened to a length of approximately 5 to 6 cm without any evident change in healing. Pedicle fixation is generally achieved with cortical bone screws, securing the pedicle to the posterior tibial cortex. Particular care in drilling and tapping through the posterior cortex will avoid injury to vessels and nerves behind the tibia. If there is any question about the stability of fixation,
Contact areas varied consistently with the angle of knee flexion. The smallest area (0.93 cm²) occurred at 0° of knee flexion. At 10°, the contact area remained low (1.1 cm²), but at 45°, it increased to a peak (2.3 cm²) and then decreased at 90° to 1.8 cm².

**Anteromedialization (8.8/8.4 mm).** The first anteromedializations provided mean anterior tibial tubercle displacement of 8.8 mm (range, 8 to 11 mm) and mean medial displacement of 8.4 mm (range, 7 to 10 mm).

At 0° of knee flexion, 8.8/8.4 mm of anteromedialization dramatically reduced contact pressure on the lateral facet. Medial facet pressure diminished (Fig. 3), and three out of five knees had no net contact pressure at 0° of knee flexion compared to medial/lateral pressures of 1.0/4.3 MPa, 0/2.5 MPa, and 0/5.0 MPa measured preoperatively.

By 10° of knee flexion, there was also improvement of the pressure distribution between medial and lateral facets. There was a 30% overall decrease in lateral facet pressure ($P < 0.02$).

By 20° of knee flexion, every patella engaged the trochlea and medial-lateral facet pressures were equalized; this equalization persisted with further flexion. There was a tendency toward slight proximal shift of the patellar contact areas with 8.8/8.4 mm anteromedialization of the patella, but the net surface areas of contact were not appreciably altered with this amount of anterior and medial tibial tubercle transfer, despite shifting of the contact areas slightly in a medial direction.

At all other angles of flexion, the medial and lateral pressures were balanced. There was a tendency toward slight superior shift of the contact area on the patella.

**Anteromedialization 14.8/8.4 mm.** Elevation of the tibial tubercle by 14.8 mm (mean of five experiments) resulted in slight reduction of medial facet pressure (Fig. 3), but considerable decrease of lateral facet pressure at 0° of knee flexion.

At 10° of knee flexion, both medial and lateral facet pressures decreased substantially, with a mean lateral facet pressure reduction of 65% compared to the preoperative mean lateral facet pressure.

By 20° to 30° of knee flexion, there was reduction and equalization of medial and lateral facet pressures compared to the measurements before anteromedialization and with less (8.8/8.4 mm) anteromedialization.

With further knee flexion, the medial-lateral facet pressure distribution remained balanced, but absolute pressures were not decreased significantly compared to preoperative values.

There was slight proximal migration of the contact area with 14.8/8.4 mm of anteromedial tibial tubercle transfer. Again, there was no significant change in the overall area and the medial area tended to enlarge as the lateral area diminished, especially at low knee flexion angles.

**DISCUSSION**

This surgical procedure is highly successful for anterior displacement of the tibial tubercle (without bone graft) to relieve patellofemoral contact stress. Rigorous objective assessment of these patients has produced very satisfying results, without several of the major complications (infection, skin slough, and compartment syndrome) reported with alternate procedures.

Anteromedial tibial tubercle transfer for persistent patellofemoral pain and articular degeneration may have several advantages over anterior displacement of the tibial tubercle with bone graft, but the ultimate result may not be significantly different, since the final goal is similar. Since distraction of the tibial tubercle pedicle is avoided with anteromedialization, no bone graft is necessary. This alone is an important advantage. Because the cut surfaces of bone are not distracted from each other, there is better control of bleeding from the cut bony surfaces with tamponading of much of the surface. Suction drainage may be used, therefore, without causing as much continuous blood ooze from the cut tibia, and the risk of a compartment syndrome or hematoma must be less. Fixation of the tibial tubercle bone pedicle is quite firm, and early motion is tolerated well when the operation is done correctly. This is an important advantage of the procedure. Pain is not usually a problem by the 2nd postoperative day, and the majority of patients go home in a knee immobilizer within 3 days of surgery.

The mechanical tests reported in this study show that anteromedial tibial tubercle transfer helps unload a degenerating patella, particularly the lateral facet. We believe that there are less severe complications and more consistent healing and recovery than with alternate procedures. Although anteromedial shift of the tibial tubercle was recommended initially for realignment of the extensor mechanism, it has become more desirable now for patients with degenerative changes in the patellofemoral joint, as an alternative to the Maquet procedure in patients with malalignment. When anteriorization of the tibial tubercle is along a steep oblique osteotomy plane (Fig. 4), there is no need for bone grafting or distraction of cut bone surfaces. A small amount of bone graft may be added if desired, in the oblique osteotomy site to offset medialization and add slightly more anteriorization in selected cases, however.

Computerized tomography has demonstrated that lateral release is quite effective for relieving tilt of the patella and that soft tissue realignment of the patella with slight ad-
vancement of the vastus medialis obliquus may be most appropriate for realignment of a subluxating patella when there is little or no arthrosis and lateral release alone provides insufficient medialization. Anteromedial tibial tubercle transfer offers an excellent alternative for the patient with persistent pain associated with patellar arthrosis or breakdown of the patellar articular surface, particularly when these are associated with lateral tilt of the patella. In addition to a lateral release to relieve tilt,13 and the option of advancing the vastus medialis obliquus to correct subluxation, this operation offers the possibility of providing up to 1.5 cm of anterior displacement of the tibial tubercle, giving relief of patellofemoral contact stress, as demonstrated in the “Results” section. This study has shown that anteromedial tibial tubercle transfer can substantially diminish contact loads on the patella. A 65% decrease in lateral facet pressure was achieved at an average anterior displacement of 14.8 mm with the knee flexed 10°. The actual location of the patellar contact area changed such that contact pressures were shifted medially and slightly more proximal on the articular surface of the patella. With this surgical technique, it is possible to shift and balance contact pressure while diminishing contact stress.

In general, when anteriorization of the tibial tubercle is needed, we recommend 12 to 15 mm of anteriorization in order to achieve the more notable reduction of patellar contact stress reported in this study with this amount of anteriorization. This surgical procedure, however, should not be used unless extensive conservative treatment has failed to give relief and less demanding surgical techniques, such as lateral retinacular release, do not adequately relieve the mechanical disorder identified.

ACKNOWLEDGMENTS

We thank the patients who returned so willingly for followup. We also would like to thank Harry Gossling for support and guidance, Susan Hill for help with manuscript preparation, Joanne Andersen of the Newington Veteran’s Administration Hospital for help with illustrations, John Goldberg and David Leslie for use of their Instron 1113, Romeo LeSage for help in obtaining cadaver specimens, and Yoshikazu O’Hara for helping to quantify tibial tubercle anteriorization.

REFERENCES


DISCUSSION

Jack H. Henry, MD, San Antonio, Texas: Dr. Fulkerson and associates have reported on 30 patients in whom they moved the tibial tubercle anteriorly and medially by a method they have previously described. Although this is not a large series, their followup was 3 years and their method
of evaluation was good. Ninety-three percent good and ex-
cellent results speaks for itself. Furthermore, they have
evaluated their technique by measuring forces in cadaver
knees. However, we should be reminded that cadaver knees
do not reproduce the forces produced in the dynamic patel-
lofemoral joint of the running athlete.

We all know there is a high complication rate after the
Maquet procedure. The authors have had their share of
complications. Nine of 25 patients' knees needed to be
manipulated before using the continuous passive motion
machine. One tibial tubercle fractured, one tibial tubercle
avulsed, and 16 screws had to be removed. They were able
to avoid skin sloughs. The authors advise that this procedure
be tried on cadaver knees before starting on a patient. I
wholeheartedly agree. The advantage of this technique is
that it does not require bone grafting. I emphasize the
authors' point that this technique must be combined with
lateral release, if one is careful not to cut the vastus lateralis
tendon.

One of the most important points of this paper is that not
all patients with patellofemoral subluxation start with the
same anatomy. Therefore, an operation to repair or recon-
struct the patellofemoral joint cannot be a cookbook proce-
dure. All patients require variations in technique. Hughston
taught us the importance of intraoperative evaluation. I have
taken down patellofemoral reconstructions three and four
times before accepting the patellar glide; however, once it is
obtained, it works. Finally, I urge caution in operating on
the basis of radiographic and CT findings. We should depend
on clinical history and physical examination and be guided
by intraoperative findings.

I would like to ask the authors if they opened the joint
and inspected for other abnormalities, and if so, what did
they find? Were the results affected if the patellae were
shaved arthroscopically or with arthrotomy? I congratulate
them on a good paper, well done.

Authors' Reply: We appreciate Dr. Henry's careful consid-
eration of our work. As Dr. Henry has indicated, we encoun-
tered knee stiffness in 36% of our patients before starting
early motion. This is not, however, a problem anymore. We
encourage early motion and believe this to be an important
advantage of this technique over some alternate techniques,
as the fixation strength is quite secure, particularly with two
cortical lag screws. Screw removal after healing of the oste-
otomy is almost a routine part of the procedure at this point.

Dr. Henry's comments are quite appropriate regarding
practice on cadaver knees. In particular, the student of this
surgical technique should note the anterior tibial artery and
peroneal nerve at the back of the anterior compartment at
the time of cadaver dissection. These structures must be
rigorously avoided at the time of surgery.

In response to Dr. Henry's specific questions, we have
found only one patient in our series who had significant
other intraarticular abnormalities at the time of surgery.
This patient had a lateral meniscus flap tear. We include
arthroscopy in all patients undergoing anteromedial tibial
tubercle transfer as part of the initial evaluation before
proceeding to the osteotomy. The patellar and trochlear
articular surfaces can thus be accurately evaluated to be
certain that anteromedial tibial tubercle transfer is most
appropriate. Finally, in response to Dr. Henry's last ques-
tion, I believe that removing loose flakes or flaps of articular
cartilage on the patella at the time of tibial tubercle anter-
omedialization is appropriate. The real benefit of this pro-
cedure, though, is redistributing contact pressures, hopefully
onto healthier articular cartilage in the majority of patients.

We now have over 8 years of experience with this surgical
procedure, and the long-term results have been very stable
in the majority of patients. This technique is extremely
helpful in the management of patients with lateral facet and
distal medial facet arthrosis related to malalignment.